

Race, infection, and arteriosclerosis in the past

Dora L. Costa^{*†}, Lorens A. Helmchen[‡], and Sven Wilson[§]

^{*}Department of Economics, Massachusetts Institute of Technology, E52-274C, 50 Memorial Drive, Cambridge, MA 02142; [‡]School of Public Health, University of Illinois, 1603 West Taylor Street, Chicago, IL 60612-4394; and [§]Department of Political Science, Brigham Young University, SWKT 830, Provo, UT 84602

Edited by Ronald W. Jones, University of Rochester, Rochester, NY, and approved May 3, 2007 (received for review December 13, 2006)

We document racial trends in chronic conditions among older men between 1910 and 2004. The 1910 black arteriosclerosis rate was six times higher than the white 2004 rate and more than two times higher than the 2004 black rate. We argue that blacks' greater lifelong burden of infection led to high arteriosclerosis rates in 1910. Infectious disease, especially respiratory infections at older ages and rheumatic fever and syphilis at younger ages, predicted arteriosclerosis in 1910, suggesting that arteriosclerosis has an infectious cause. Additional risk factors for arteriosclerosis were being born in the second relative to the fourth quarter, consistent with studies implying that atherogenesis begins *in utero*, and a low body mass index, consistent with an infectious disease origin of arteriosclerosis.

atherosclerosis | epidemiological transition | inflammation

Older black men today not only die earlier, they also look at least 10 years older than their white counterparts, epidemiologically speaking. Among black men ages 50–64 in 1999–2004, 3% are sclerotic and 65% are hypertensive, rates not seen among white men until ages 60–74. Black men ages 60–74 are more likely to have high serum cholesterol levels (a risk factor for heart disease) and lower high-density-lipoprotein cholesterol levels (a protective factor for heart disease) than whites.[†] Black men ages 65–74 in 2003 were 1.5 times as likely as white men to die from any cause and 1.6 times as likely as white men to die from circulatory disease.[‡]

Differences in black–white mortality rates at older ages have persisted for more than a century. In the death registration states in 1900, black men's mortality rate at ages 65–74 was 1.5 times that of whites and did not consistently fall below white men's mortality rate of 5,913 per 100,000 in 1900 until 1975 (1). Because of the lack of data, previous research has not been able to determine whether differences in black and white disease rates are as persistent as racial differences in mortality rates.

We present evidence on long-run trends in black and white chronic conditions at older ages by using samples of Union Army veterans and comparing their chronic disease prevalence rates with those seen in modern populations. Because blacks at the beginning of the 20th century were of poorer nutritional status and faced a greater lifelong exposure to infectious disease than whites (2, 3), we can examine whether the survivors of adverse environments are in better health because of selection of the fittest or whether they are in worse health because of “scarring.” Our comparison also enables us to examine whether the distinction between infectious and chronic diseases underlying the theory of the epidemiological transition is accurate. This theory specifies that the world has undergone three disease stages (4): (i) the age of pestilence and famine in which life expectancy is low and the leading causes of death are such infectious and parasitic diseases as influenza, tuberculosis, and diarrhea; (ii) the stage of receding pandemics characterized by mortality declines; and (iii) the age of degenerative and manmade diseases, in which mortality stabilizes at low levels and deaths are from such chronic diseases as cardiovascular conditions and diabetes. In the United States, the black population experienced the second stage later than whites; the start of the sustained decline in black child mortality rates lagged behind those in white children by 20–30 years (2).

We test whether infectious disease and chronic conditions are unrelated, as postulated by the theory of the epidemiological transition, and whether infectious disease has a scarring effect by examining the determinants of chronic disease rates among black and white Union Army veterans. A growing body of evidence has shown that high infectious disease rates can produce high chronic disease prevalence rates because infections (i) reduce nutritional status by decreasing food intake and increasing body loss of protein and most vitamins and minerals, (ii) can cause direct organ damage, and (iii) can cause inflammation that contributes to atherosclerosis (a form of arteriosclerosis), thromboses, and organ damage (5–7). Inflammatory markers that are risk factors for heart attack and stroke are elevated during lower respiratory tract infections and during infections such as rheumatic fever, syphilis, diarrhea, malaria, and tuberculosis (7–10). Diverse bacteria have been found in the atherosclerotic lesions of patients with coronary heart disease but not in controls (11, 12).

Infections may play a role in the initiation, progression, and destabilization of atherosclerotic plaques. Influenza vaccination is associated with a 50% reduction in the incidence of sudden cardiac death, acute myocardial infarction (AMI), and ischemic stroke, suggesting that winter peaks in stroke and AMI may arise from a destabilization of atherosclerotic plaques (13). Longitudinal studies link exposure to stress in early life (including nutritional and other insults *in utero* and in infancy) to the onset of chronic diseases at middle and late ages, and with shortened waiting time to death (14–20). The exact mechanisms behind these links are still unconfirmed. Maternal malnutrition during winter may lead to retarded fetal growth (19) and metabolic changes that increase susceptibility to infectious disease.^{**} Alternatively, maternal respiratory infections during the winter months may lead to placental inflammation that impairs fetal growth (7).

If adverse environmental conditions lead to scarring, we anticipate that black Union Army veterans will have higher prevalence rates for older-age chronic conditions, particularly for heart disease and arteriosclerosis, than whites. We also anticipate that prevalence rates for both white and black Union Army veterans will be high relative to those observed in more recent populations. Finally, we hypothesize that, among Union Army veterans, observations of recent respiratory infections, infectious disease earlier in life, and

Author contributions: D.L.C., L.A.H., and S.W. designed research; D.L.C., L.A.H., and S.W. performed research; D.L.C., L.A.H., and S.W. analyzed data; and D.L.C. wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission.

Abbreviation: BMI, body mass index.

[†]To whom correspondence should be addressed. E-mail: costa@mit.edu.

[‡]Calculated from the 2003–2004 National Health and Nutrition Examination Survey IV. Men were defined to be sclerotic if the ankle brachial pressure index in either the right or left leg was <0.7. Hypertension was defined as either taking antihypertensive medication, systolic blood pressure of at least 140 mmHg, or diastolic pressure of at least 90 mmHg. High serum total cholesterol levels are levels \geq 240 mg/dl. Low levels of high-density lipoproteins are levels <40 mg/dl.

[§]Data taken from worktable 12: *Death Rates for 358 Selected Causes, by 10-Year Age Groups, Race, and Sex: United States, 1999–2003*, Oct. 12, 2006, www.cdc.gov.

^{**}*In utero* exposure to famine in the last trimester leads to lower birth weight and shorter body length than earlier exposure, but studies of older age outcomes reveal that there are different critical time windows for different organ systems (21, 22).

© 2007 by The National Academy of Sciences of the USA

month of birth predict arteriosclerosis at older ages. We also hypothesize that body mass index (BMI) is negatively correlated with older-age arteriosclerosis because repeated acute or chronic infectious disease will lead to poor current net nutrition. In contrast, in a modern population we might expect a positive correlation because of obesity. (Very few men in the Union Army sample are overweight.)

Previous evidence on health outcomes for historical populations shows a relationship between childhood mortality rates and later cohort mortality, including those from arteriosclerotic heart disease (6, 17). We present evidence on the relationship between the actual incidence of infectious disease and arteriosclerosis in a past population. We focus on arteriosclerosis because of its role in mortality and because it is one of the quintessential degenerative diseases.

Data and Methods

Our findings are based on two longitudinal data sets created from the military and pension records of Union Army veterans (available at www.cpe.uchicago.edu). The white sample is based on the service records of $\approx 35,000$ men, and the black sample is based on the service records of $\approx 6,000$ men. The military service records provide information on events such as wartime injury and illness, age, and place of enlistment.

Both white and black veterans were eligible for a pension for war-related injuries, but because relatively few blacks were in fighting units, most African-American veterans could not claim a war-related injury. Before 1890, the Pension Bureau admitted 81% of white applicants onto the pension rolls but only 44% of black applicants. However, beginning in 1890, pensions were paid for any disability, regardless of its relation to the war, and the Pension Bureau began to consider age 65 or older a disability in its own right unless men were “unusually vigorous.” By 1907 old age (defined as age 62+) was officially recognized by Congress as a disability. Among all men who identified themselves as Union veterans in the 1910 census, we found 86% of the white veterans and 79% of the black veterans in the pension records. Among pension applicants under the 1890 law, 74% of blacks applying between 1890 and 1899 had their pension application approved by 1899 compared with 82% of whites. Pension awards under the 1890 law ranged from \$6 to \$12 per month, and the mean pension award was 80¢ higher for whites than blacks.

Pension applications included detailed medical examinations both for men whose pension application or bid for a pension increase was rejected and for men whose bid for a pension increase was accepted. A surgeons’ examination is available for 93% of all men who had a pension in 1900. Men for whom a surgeons’ examination is missing tended to be men who entered at a late age and received a pension on the basis of age. Although we assume that these men did not have the specific chronic conditions that we examine, our estimates of prevalence rates are virtually the same when we omit these men from the sample.

The white Union Army sample is representative of the general Northern population before the war in terms of wealth and circa 1900 in terms of mortality experience (23). The black sample draws disproportionately from Northern states, where the proportion of age-eligible men who served was greater among blacks than among whites. Twenty-six percent of all recruits came from the free states, 22% from the border states and the District of Columbia, and 50% from the Confederacy. Three-quarters of all Colored Troops were former slaves. In the Confederacy there were active recruitment efforts whenever an area was liberated by the Union Army. Thus, states that were occupied before the end of the war provided the most men (24).

The records of the examining surgeons include detailed descriptions of broad disease groups (e.g., cardiovascular or respiratory). For example, for the heart physicians described pulse rate characteristics: whether a murmur was present and its timing, type, and location and which valves were involved; whether the murmur was

accompanied by a thrill; and whether there was enlargement, edema, cyanosis, dyspnea, arteriosclerosis, or impaired circulation. Respiratory examinations included reports of respiratory sounds such as murmurs, rales, crepitation, vocal fremitus, and ronchae, and decreased breath sounds. Disease rates are based on an examining surgeon ever having noted a specific condition, symptom, or sign. Prevalence rates for 1910 may be underestimated because men who qualified for a pension on the basis of age, as many did in 1910, have fewer surgeons’ exams than their counterparts who qualified on the basis of health.

The examining physicians often provided summary disability ratings for each broad disease group that were used by the Pension Bureau to determine the size of the pension award. Whites had a significantly higher probability of being rated across almost all disease categories, sometimes two to four times as high. The exceptions to this were cardiovascular disease, arthritis and other musculoskeletal conditions, and injuries. In rating veterans, examining surgeons were more likely to designate whites than blacks as disabled. For example, by 1900, 4.5% of black examinees were blind in at least one eye, compared with 4.0% of white examinees, but among these blind veterans the examining surgeons rated only 44% of blacks as disabled compared with 88% of whites. Given the systematic downward bias in designating blacks as disabled relative to whites, it is highly likely that examining physicians underreported the chronic conditions of blacks relative to whites.

We compare the Union Army data with random samples of the noninstitutionalized population drawn from the 1971–1975, 1976–1980, 1988–94, and 1999–2004 National Health and Nutritional Examination Surveys (I, II, III, and IV). These surveys include medical exams, which, while not strictly comparable across all years, yield descriptions and diagnoses that can be compared with those of physicians working under contract from the Pension Bureau. The symptoms, signs, and conditions that we examine did not require any diagnostic equipment that was unavailable to late 19th-century physicians. These symptoms, signs, and conditions are arteriosclerosis (detected by feeling whether the arteries had hardened), valvular heart disease (murmurs involving the mitral and aortic valves), congestive heart failure (concurrent presence of edema, cyanosis, and dyspnea), murmurs, irregular pulse, adventitious sounds (murmurs, rales, crepitation, vocal fremitus, and ronchae), decreased breath sounds, joint problems, and back problems. Signs such as adventitious sounds and decreased breath sounds may be indicators of respiratory infections or chronic conditions. Signs such as murmurs and irregular pulse may be indicators of heart conditions.

We compare prevalence rates by race for Union Army veterans ages 50–64 in 1900 and 60–74 in 1910 with point prevalence rates for men in the same age groups from more recent health surveys. By examining men in 1900 and 1910 we can obtain large numbers of men in those age groups. We use population weights for men in recent health surveys and weight our prevalence rates for black veterans by the geographic distribution of the black population in 1900 in the four census regions. The Union Army samples are restricted to men on the pension rolls by 1900 and 1910.

We investigate the determinants of the probability of developing arteriosclerosis between 1900 and 1910 by using a series of probit models. The typical probit equation that we estimate is:

$$\Pr(A_{1910} = 1 | A_{1900} = 0) = \Pr(\varepsilon < X'\beta) = \Phi(X'\beta),$$

where A_1 is equal to one if the veteran had arteriosclerosis at time t ($= 1900, 1910$), $\Phi()$ is a standard normal cumulative distribution function, and X is a vector of control variables. The effect of a unit change in one of the independent variables on the probability of having arteriosclerosis is given by the partial derivative of the probit function Φ with respect to that independent variable ($\partial P / \partial X$). Our control variables include chronic conditions and signs in 1900 in our first specification, chronic conditions and signs in 1910 in our

Table 1. Prevalence rates (per 100 men) of chronic conditions, symptoms, and signs in 1900 and 1910

Condition	Prevalence rate, %			
	Age 50–64 in 1900		Age 60–74 in 1910	
	Black	White	Black	White
Irregular pulse	47.3	32.4	60.4	43.7
Murmur	36.9	27.9	39.7	38.7
Valvular heart disease	22.0	19.2	26.0	26.9
Congestive heart failure	1.1	2.7	47.4	8.9
Arteriosclerosis	2.4	1.7	16.0	9.2
Adventitious sounds	16.5	20.1	20.3	29.1
Decreased breath sounds	15.3	11.9	22.6	15.4
Joint problems	51.4	43.2	60.7	55.0
Back problems	47.5	39.2	55.0	47.5

Prevalence rates for black men in 1900 and 1910 are weighted by the geographic representation of the black population in the four census regions in 1900.

second specification, war-time illnesses in our third specification, and war-time illnesses and quarter of birth in our fourth specification. All regressions control for age in 1910 and occupation circa 1900. The first three regressions control for race. Our fourth specification is restricted to white veterans because month of birth is unavailable for blacks.

Results

Trends. In 1900 black veterans at ages 50–64 had higher rates of joint problems, irregular pulse, and murmurs than whites in the same age group but for the most part, resembled their white counterparts (see Table 1). Ten years later, at ages 60–74, black rates of arteriosclerosis and congestive heart were much higher than those of whites. Sixteen percent of blacks had arteriosclerosis compared with 9% of whites, and 47% of blacks had congestive heart failure compared with 9% of whites.

Prevalence rates for both blacks and whites were much higher than in recent surveys (see Table 2). Prevalence rates for the average combined category of decreased breath and adventitious sounds fell by 0.2% points per year for both whites and blacks between 1900 and 1910 and 1988–1994. For men ages 50–64 prevalence rates for musculoskeletal conditions fell by 0.5% points per year from 1910 to 1988–1994 for black men and by 0.4% points per year for white men. Within the same age group prevalence rates for the combined category of arteriosclerosis, valvular heart disease, and congestive heart failure fell by 0.4% points from 1910 to 1976–1980 for black men and by 0.2% points per year for white men. Prevalence rates for blacks were higher for almost all conditions, symptoms, and signs between 1971 and 2004.

How reliable are these estimates of declines in prevalence rates? Physicians diagnosed arteriosclerosis by feeling a literal hardening of the arteries. A medical text of the era notes, “The increased arterial tension, thickening of the temporal, radial, bronchial, and femoral arteries, which may be recognized by the hard, cordlike feel; the hypertrophy of the left ventricle, as shown by dullness to the left and downwards; and the accentuation of the second aortic sound, make a group of symptoms that can hardly be mistaken for those of any other lesion” (25). The examining surgeons’ use of hard arteries as a detection criterion provides evidence of peripheral arteriosclerosis that may be evidence of atherosclerosis (cholesterol and fatty plaques in the blood) and suggests other associated diseases such as diabetes mellitus or local inflammations. A more precise diagnosis of congestive heart failure might include not only edema, cyanosis, and dyspnea, but also cardiomegaly, and exclude coexisting respiratory infection and asthma. This definition reduces the prevalence rate of congestive heart failure to 6.1% among white men ages 60–74 and 34.9% among black men of the same age.

Prevalence rates calculated from the Union Army sample are not strictly comparable to the point prevalence rates estimated from recent surveys because the pension system did not obtain exams at the same point in time. Two possible biases exist. First, because the Union Army rates are based on multiple exams, Union Army prevalence rates may be overstated relative to a case where a single examination occurred. It seems unlikely that such a large decline in prevalence rates could be explained by definitional biases alone. Second, the Union Army prevalence rate is calculated based on the health of the veteran at the last available examination before the analysis points of 1900 and 1910, in some cases several years before. This bias will understate the true prevalence. Thus, although estimated prevalence rates may not be precise indicators of true prevalence rates, there is little doubt that disease prevalence rates in the Union Army sample were much higher than they are today.

The higher prevalence rates of joint problems among blacks relative to whites are to be expected because of manual labor predominance among blacks. Circa 1900 22% of white veterans were professionals or proprietors compared with 5% of black veterans. Manual occupations at both young adult ages and older ages were strong predictors of older-age musculoskeletal conditions among white veterans (26).

The declining disease rates in Tables 1 and 2 are readily reconciled with changes in cause of death patterns observed during epidemiological transitions. Cause of death information may be a poor indicator of morbidity rates when infectious disease rates are high. Table 3 shows that blacks were less likely to die of heart and cerebrovascular disease than whites, but were more likely to die of bronchitis, pneumonia, or influenza, infectious disease, and genitourinary disease. Among veterans who had arteriosclerosis in 1910, only 39.6% of blacks died of either heart or cerebrovascular disease compared with 49.7% of whites; 18.8% of blacks who had arteriosclerosis died from bronchitis, pneumonia, or influenza.

Cause of death recording may be less accurate for blacks than for whites, thereby leading to underestimates of heart disease among blacks. However, cause of death is unknown for 49% of whites and 51% of blacks, not a large difference. Among men with known causes of death, 4% of whites have a vague cause of death (e.g., “old age”) compared with 5% of blacks.

Consequences and Causes of Arteriosclerosis Among Union Army Veterans. A diagnosis of arteriosclerosis in 1910 was the most important chronic condition that predicted 10-year mortality rates among black veterans ages 60–74 in 1910. In a probit regression (data not shown) controlling only for age, arteriosclerosis in 1910 increased blacks’ mean 10-year mortality rates of 0.601 by 0.106 ($\hat{\sigma} = 0.053$). Valvular heart disease, congestive heart failure, and respiratory problems in 1910 were not statistically significant predictors of 10-year mortality rates for blacks. In contrast, for whites, valvular heart, congestive heart failure, irregular pulse, and adventitious sounds all were statistically significant predictors of mortality rates, and arteriosclerosis was a statistically significant predictor only at the 10% level of significance.

Infection was a statistical predictor of developing arteriosclerosis between 1900 and 1910 (see Table 4). A sexually transmitted disease increased the probability of arteriosclerosis by 0.09. A comparison of the first and second regressions in Table 4 shows that new cases of arteriosclerosis in 1910 were also correlated with new cases of adventitious sounds, which increased the probability of arteriosclerosis by 0.03. Adventitious sounds may be indicators of respiratory infections. In addition, diabetes increased the probability of developing arteriosclerosis by 0.07, congestive heart failure by 0.06, valvular heart disease by 0.02, and new cases of bradycardia by 0.03. Because wartime rheumatic fever caused valvular heart disease and congestive heart failure (26), rheumatic fever, not these heart conditions, may have led to arteriosclerosis. As hypothesized, BMI, measured at ages 50–64, was a negative predictor of arteriosclerosis.

Table 2. Prevalence rates (per 100 men) of conditions, symptoms, and signs, 1900–2004

Condition	Race	Prevalence rate, %				
		1900–1910	1971–1975	1976–1980	1988–1994	1999–2004
Ages 50–64 in 1900						
Irregular pulse	B	47.3	5.0	5.9	7.7	6.1
	W	32.4	3.5	3.4	1.9	4.0
Murmur	B	36.9	5.6	6.4	3.6	3.0
	W	27.9	2.6	3.7	1.9	1.5
Valvular heart disease	B	22.0	2.8	6.4		2.1
	W	19.2	2.5	3.4		0.2
Congestive heart failure	B	1.1		7.0	6.3	5.3
	W	2.7		4.2	3.7	3.4
Arteriosclerosis	B	2.4	2.8	0.5		2.8
	W	1.7	1.6	0.4		0.6
Adventitious sounds	B	16.5	5.1	9.0	4.2	
	W	20.1	5.1	6.0	3.5	
Decreased breath sounds	B	15.3	4.2	3.5	5.4	
	W	11.9	4.2	7.4	5.0	
Joint problems	B	51.4	8.5	15.4		
	W	43.2	8.5	8.8		
Back problems	B	47.5	22.0	20.7	27.2	
	W	39.2	22.0	24.9	34.3	
Ages 60–74 in 1910						
Irregular pulse	B	60.4	7.7	4.3	10.1	15.5
	W	43.7	7.1	8.4	7.8	9.7
Murmur	B	39.7	9.8	9.9	3.6	3.6
	W	38.7	6.6	7.6	3.5	2.3
Valvular heart disease	B	26.0	3.4	9.3		1.5
	W	26.9	2.6	5.5		1.2
Congestive heart failure	B	47.4		9.7	7.8	4.5
	W	8.9		9.5	5.6	7.0
Arteriosclerosis	B	16.0	4.2	2.8		7.0
	W	9.2	1.6	1.6		2.7
Adventitious sounds	B	20.3	11.6	10.4	3.9	
	W	29.1	7.9	10.5	4.0	
Decreased breath sounds	B	22.6	3.3	10.1	8.8	
	W	15.4	12.9	11.6	7.3	
Joint problems	B	60.7	2.5	10.6	14.0	
	W	55.0	9.1	12.3	13.1	
Back problems	B	55.0	32.2	24.0	26.9	
	W	47.5	29.5	39.8	31.2	

B, black; W, white. See Table 1 on the weighting of black sample in 1900 and 1910. Data for 1971–2004 are from National Health and Nutritional Examination Surveys and use sample weights. All prevalence rates are physician-reported with the exception of congestive heart failure in 1988–1994, which is self-reported, and murmur, valvular heart disease, and congestive heart failure in 1999–2004, which are self-reported. Unlike earlier surveys, arteriosclerosis in 1999–2004 is not based on physician impressions but on an ankle brachial pressure index in either the right or left leg that was < 0.7 .

sis, with each additional BMI unit increasing the probability of arteriosclerosis by 0.003.

Rheumatic fever, syphilis, and unspecified fever during the war predicted arteriosclerosis (see Table 5), increasing its probability by 0.06, 0.07, and 0.02, respectively. Rheumatic fever during the war

also predicted a higher prevalence of congestive heart failure, an irregular pulse, and valvular heart disease in 1900. Height at enlistment and size of city of residence (data not shown) were not statistically significant predictors of later arteriosclerosis. When we ran the specifications separately for whites and blacks (data not shown), the point estimates were similar for both blacks and whites.

White men born in the second quarter were more likely to develop arteriosclerosis between 1900 and 1910 than men born in the fourth quarter (see Table 5). A second-quarter relative to a fourth-quarter birth date increased the probability of arteriosclerosis by 0.02. There is no evidence that season of birth effects arises from social differences in the distribution of births, mortality selection during the war, or mortality selection effects early in life (27).

Month of birth was not a statistically significant predictor of other chronic conditions in 1910 (regressions not shown), but it was a statistically significant predictor of the probability of the surgeons' recording a nonsexually transmitted infectious disease in 1910 (the coefficient on the second quarter relative to the fourth-quarter dummy was 0.025, $\hat{\sigma} = 0.015$). It was also a statistically significant predictor of the surgeons' noting valvular heart disease in 1900 (the

Table 3. Causes of death by race, men ages 60–74 in 1910

Cause of death	Percentage	
	Black	White
Heart and cerebrovascular	34.8	46.1
Cerebrovascular	6.7	13.1
Heart	28.1	33.0
Bronchitis, pneumonia, and influenza	16.3	9.7
Infectious	3.6	1.9
Genitourinary	14.9	12.5
Cancer	2.1	6.4
Paralysis	4.3	2.3
Other	24.0	21.1

Calculated from the Union Army data.

Table 4. Chronic and infectious conditions and signs predicting new cases of arteriosclerosis between 1900 and 1910, Probit

Conditions/signs	Probability of cases observed by 1900		Probability of cases observed by 1910	
	$\partial P/\partial X$	SE	$\partial P/\partial X$	SE
Infectious disease				
Sexually transmitted disease	0.085**	0.049	0.089***	0.040
Other infectious disease	0.003	0.010	0.001	0.009
Sign of respiratory infection or chronic disease				
Adventitious sounds	0.008	0.009	0.027***	0.008
Decreased breath sounds	0.043*	0.019	0.007	0.020
Chronic condition				
Valvular heart disease	0.023***	0.009	0.051***	0.008
Congestive heart failure	0.060***	0.023	0.075***	0.015
Diabetes	0.074***	0.031	0.047***	0.021
Cardiovascular sign				
Tachycardia	0.002	0.009	0.009	0.007
Bradycardia	0.006	0.019	0.031**	0.016
Irregular pulse	0.021***	0.008	0.037***	0.007
BMI at age 50–64	0.003***	0.001	0.002**	0.001
Dummy = 1 if black	0.082***	0.021	0.066***	0.021
Pseudo R^2	0.030		0.080	

Data are based on 6,410 observations. All conditions and signs are dummy variables. The regressions also control for age in 1910 and two occupational dummies indicating if circa 1900 the veteran was a farmer or a professional, proprietor, or artisan. (Laborer is the omitted occupational dummy variable.) ***, $P < 0.01$; **, $P < 0.05$; *, $P < 0.10$. The sample is restricted to men who were on the pension rolls in 1900 and who had a surgeons' exam indicating that they did not have arteriosclerosis in 1900.

coefficient on the second quarter relative to the fourth-quarter dummy was 0.036, $\hat{\sigma} = 0.017$) and of their noting an irregular pulse in 1900 (the coefficient on the second quarter relative to the fourth-quarter dummy was 0.041, $\hat{\sigma} = 0.020$). However, even controlling for infectious conditions in 1910 and valvular heart disease and irregular pulse in 1900, month of birth was still a statistically significant predictor of arteriosclerosis.

Month of birth was not a predictor of arteriosclerosis in National

Health and Nutritional Examination Surveys I and II among men ages 60–74 (results not shown), even though month of birth significantly influenced mortality rates among men in this cohort (19, 24). However, Union Army veterans born in either the second or third quarter were more likely to die of all causes than veterans born in the fourth quarter, and stroke death rates were highest among those born in the second quarter (27).

Even controlling for preexisting conditions, current conditions, and wartime experiences, black veterans' probability of arteriosclerosis in 1910 was 0.08 higher than that of whites, probably in part because we cannot observe all infectious disease incidence. Tests in three United States cities in the 1920s showed that $\approx 60\%$ of adults had acquired immunity to diphtheria before any artificial immunization (28), but we observe only a handful of diphtheria cases. Black wartime infectious disease rates are probably understated relative to white rates, perhaps because of the difficulty the War Department had in obtaining competent physicians for the Colored Troops (29). Although black wartime mortality rates were higher than those of whites (20% instead of 14%), and 90% of black wartime deaths were caused by disease compared with half of white wartime deaths, black veterans are listed as having had statistically significantly lower wartime rates of tuberculosis, typhoid, malaria, rheumatic fever, and diarrhea. Only cholera rates were statistically significantly higher. Higher wartime deaths but lower reported disease rates for black soldiers compared with white soldiers suggests to us that black wartime disease rates are underestimated. In the pension records, the examining surgeons noted higher rates of tuberculosis and sexually transmitted diseases among blacks than among whites, but lower rates of other infectious diseases among blacks.

Discussion

Our study shows that older black men in 1910 faced higher rates of peripheral arteriosclerosis, congestive heart failure, irregular pulse, murmurs, and joint problems than whites. Although the long-run decline in heart conditions was greater among blacks than among whites, blacks still faced higher chronic disease rates between 1971 and 2004.

Arteriosclerosis in 1910 was the single most important chronic condition predicting black mortality in 1910. Risk factors for

Table 5. Wartime illnesses and quarter of birth predicting new cases of arteriosclerosis between 1900 and 1910, Probit regression

Illness/quarter of birth	Probability			
	Total		White Only	
	$\partial P/\partial X$	SE	$\partial P/\partial X$	SE
Dummy = 1 if born				
1st quarter			0.018	0.012
2nd quarter			0.024**	0.012
3rd quarter			0.016	0.012
4th quarter				
Dummy = 1 if wartime				
Respiratory infection	0.005	0.012	0.004	0.013
Rheumatic fever	0.057***	0.013	0.052***	0.014
Diarrhea	0.006	0.008	0.006	0.009
Measles	0.000	0.013	0.007	0.015
Syphilis	0.066**	0.038	0.097***	0.047
Cholera	0.056	0.031		
Smallpox	0.044	0.037	0.051	0.043
Tuberculosis	0.034	0.030	0.051	0.035
Fever	0.020**	0.009	0.022**	0.010
Typhoid	0.009	0.013	0.009	0.015
Malaria	0.000	0.019	0.008	0.022
Injury	0.006	0.007	0.006	0.008
Dummy = 1 if black	0.075	0.019		
Pseudo R^2	0.022		0.021	
Number	6,479		5,056	

***, $P < 0.01$; **, $P < 0.05$; *, $P < 0.10$. See Table 4 for additional controls and sample restrictions.

arteriosclerosis were infectious disease at different points in the life cycle, particularly respiratory infections at older ages and rheumatic fever and syphilis at young adult ages, being born in the second quarter relative to the fourth quarter, and poor current net nutrition (as proxied by low BMI). Adverse environmental conditions led to scarring and infectious disease caused degenerative disease at older ages, contradicting the underlying assumption of the theory of epidemiological transition that infectious and degenerative diseases are separate.

Arteriosclerosis was more prevalent among blacks than among whites in 1910 because blacks had a greater lifetime burden of infection; they either had greater exposure to infection or were more susceptible to infectious disease because of poorer nutritional status. The former slaves were illiterate and owned no property, and free blacks fared little better. Contemporary observers reported a high incidence of pellagra and rickets among blacks in the post-bellum era (30). As former slaves crowded into cities after the Civil War, tuberculosis and respiratory epidemics broke out, and, because men who migrated often did so without their families, syphilis rates increased (31). Because blacks could ill afford self-protection measures against infectious disease, they particularly depended on public health campaigns such as those against hookworm (32) and investments in sanitation and water filtration, investments that were extended to black areas of town later than to white areas (33).

A large body of literature implicates upper respiratory tract infections with atherosclerosis (34), consistent with our findings. Less is known about the roles of rheumatic fever and syphilis, though, a century ago it was widely believed that these infections produced arteriosclerosis (25). Case studies of patients have found an association of early atherosclerosis with tertiary syphilis (35). Many infections, including syphilis, are associated with antiphospholipid antibodies, and these antibodies may contribute to the formation of atherosclerotic thrombosis (36). Elevated high-sensitivity C-reactive protein levels have been found not only in patients with rheumatic fever, but also in patients with chronic rheumatic valve disease, suggesting the persistence of inflammation even after the initial infection (10, 37). Modification of low-density lipoprotein (LDL) particles caused by oxidation is an important step in the process of atherogenesis, and antibodies against oxidized

LDL have been found in many diseases, including rheumatic fever (38). However, we cannot rule out that rheumatic fever and syphilis led to peripheral arteriosclerosis but not atherosclerosis.

Our findings on quarter of birth and arteriosclerosis are consistent with studies implying that atherogenesis begins *in utero* (39). Nutritional deprivation *in utero* may lead to compromised immune function and therefore to higher inflammation rates (40). Our negative correlation between BMI and arteriosclerosis may arise if men with low BMIs were suffering from infections not recorded by the examining surgeons or if much of the arteriosclerosis at the turn of the century was caused by infection and not a high-fat diet.

We do not claim that infection alone can account for atherosclerosis. Dietary patterns may influence cardiovascular disease risk through effects on inflammation and endothelial activation and may explain some of the racial differences in arteriosclerosis rates observed today. Chronic mild stress may induce or accelerate the development of atherosclerosis, suggesting that low socioeconomic status and limited legal protections may have directly worsened blacks' health outcomes.

Although we have focused on past black-white differences in arteriosclerosis, current black-white differences in atherosclerosis rates also may be explained by differences in infectious disease rates. Blacks ages 50–64 in 1999–2004 were sclerotic at rates seen among whites only at ages 60–74. In the 1940s, when those age 50–64 in 1999–2004 were children, the black death rate from influenza and pneumonia for children under age 1 ranged from 767 per 100,000 in 1949 to 1897 per 100,000 in 1940, while the white death rate ranged from 226 per 100,000 to 759 per 100,000 during those years.^{††}

^{††}Data taken from table 2, volume 43, no. 21, *Death Rates for Selected Causes by 10-Year Age Groups, Race, and Sex: Death Registration States, 1900–1932, and United States, 1933–1998*, HIST290.4049, www.cdc.gov.

We thank Matthew Kahn, Louis Nguyen, and Nevin Scrimshaw for comments and Abhijit Bhalla for research assistance. This work was supported by National Institutes of Health Grant P01 AG10120. D.L.C. was supported by National Institutes of Health Grant R01 AG19637 and the Robert Wood Johnson Foundation.

1. Bureau of the Census (1947–2002) *Vital Statistics of the United States* (Bureau of the Census, Washington, DC).
2. Haines MR (2003) *Hist Meth* 36:157–195.
3. DuBois WEB (1899) *The Philadelphia Negro: A Social Study* (Univ of Penn Press, Philadelphia).
4. Omran AR (1971) *Mil Mem Q* 49:509–538.
5. Fogel RW (1994) *Am Econ Rev* 84:369–395.
6. Crimmins EM, Finch CE (2005) *Proc Natl Acad Sci USA* 103:498–503.
7. Finch CE, Crimmins EM (2004) *Science* 305:1736–1739.
8. DeLuca M, Rossi A (1968) *G Ital Dermatol Minerva Dermatol* 109:109–116.
9. Prat C, Dominguez J, Rodrigo C, Giménez M, Azuara M, Jiménez O, Galí N, Ausina V (2003) *Pediatr Infect Dis J* 22:963–968.
10. Gölbasi Z, Uçar O, Kales T, Sahin A, Camsari A, Diker E, Aydogdu S (2002) *Eur J Heart Fail* 4:593–595.
11. Lindholdt JS, Fasting H, Henneberg EW, Ostergard L (1999) *Eur J Vasc Endovasc Surg* 17:283–289.
12. Ott SJ, El Mokhtari NE, Musfeldt M, Hellmig S, Freitag S, Rehman A, Kühbacher T, Nikolaus S, Namsolleck P, Blaut M, et al. (2006) *Circulation* 113:929–937.
13. Meyers DG (2003) *Curr Atheroscler Rep* 5:146–149.
14. Barker DJP (1992) *Foetal and Infant Origins of Adult Disease* (BMJ Publishing, London).
15. Barker DJP (1994) *Mothers, Babies, and Disease in Later Life* (BMJ Publishing, London).
16. Barker DJP (2003) *The Best Start in Life* (Century, London).
17. Bengtsson T, Lindstrom M (2003) *Int J Epidemiol* 32:286–294.
18. Blackwell D, Hayward M, Crimmins CE (2001) *Soc Sci Med* 52:1269–1284.
19. Dobhammer G, Vaupel JW (2001) *Proc Natl Acad Sci USA* 98:2934–2939.
20. Preston SH, Hill ME, Drevenstedt GL (1998) *Soc Sci Med* 47:231–246.
21. Ravelli GP, Stein ZA, Susser MW (1976) *N Engl J Med* 295:349–353.
22. Ravelli AC, van der Meulen JH, Michels RP, Osmond C, Barker DJ, Hales CN, Blecker OP (1998) *Lancet* 351:173–177.
23. Costa DL (1998) *The Evolution of Retirement* (Univ Chicago Press, Chicago).
24. Costa DL, Kahn ME (2006) *J Econ Hist* 66:936–962.
25. Thomas RL (1907) *The Eclectic Practice of Medicine* (Scudder Brothers, Cincinnati).
26. Costa DL (2000) *Demography* 37:53–72.
27. Costa DL, Lahey JN (2005) *J Eur Econ Assoc* 3:487–493.
28. Collins SD (1937) *Public Health Rep* 51:1736–1773.
29. Glatthaar JT (1990) *Forged in Battle* (Louisiana State Univ Press, Baton Rouge, LA).
30. Kiple KF, VH King (1981) *Another Dimension to the Black Diaspora: Diet, Disease, and Racism* (Cambridge Univ Press, New York).
31. Costa DL (2004) *Working Paper 10902* (National Bureau of Economic Research, Cambridge, MA).
32. Bleakley HC, Jr (2007) *Q J Econ* 122:73–117.
33. Troesken W (2004) *Water, Race, and Disease* (MIT Press, Cambridge, MA).
34. Muhlestein JB, Anderson JL (2003) *Cardiol Clin* 21:333–362.
35. Hajjii L, Alami M, Ghannam R, Sadeli M, el Moktadir N, Benjelloun H, Benomar M, Benomar M (1998) *Arch Mal Coeur Vaiss* 91:1183–1186.
36. Vaarala O (1996) *Lupus* 5:442–447.
37. Chiu-Braga YY, Hayashi SY, Schafranski M, Messias-Reason IJ (2006) *Int J Cardiol* 109:275–276.
38. Steinerová A, Racek J, Stozicky F, Zima T, Fialová L, Lapin A (2001) *Physiol Res* 50:131–141.
39. Painter RC, de Rooij SR, Bossuyt PM, Simmers TA, Osmond C, Barker DJP, Bleker OP, Roseboom TJ (2006) *Am J Clin Nutr* 84:322–327.
40. Moore SE, Cole TJ, Collinson AC, Poskitt EM, McGregor IA, Prentice AM (1999) *Int J Epidemiol* 28:1088–1095.